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(56) Documents Cited
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US 4532447 A

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(54) Electric machine

(57) The present invention provides an electric machine, which comprises a first stator member 1; a second stator member 2 substantially co-axial with but spaced from the first stator member 1 and adapted to co-operate therewith; an intermediate rotor member 3 located in the space between the first and second stator members and substantially co-axial therewith; at least one of the stator and/or the rotor members being adapted to rotate about its longitudinal axis and at least one of the stator and/or rotor members being provided with one or more magnetic or magnetisable members, which magnetic or magnetisable member is adapted to provide a magnetic field which acts upon an adjacent one or more of the rotor and/or stator members; means for varying the magnetic field from one or more of the stator and/or rotor members; at least one of the stator and/or rotor members being provided with means to provide a mechanical power output from or a power input to the machine. The rotor 3 comprises several members 30, carried by a spider 4, each rotatable about its own axis.

Preferably, the machine is an electric motor and rotation of the rotor is achieved by varying the frequency of the currents applied to the stator members relative to one another. The rotor members 30 may initially be caused to rotate about their individual axes by the magnetic field from the first stator and subsequent opposing field causes the whole rotor to rotate. The machine may be a motor, generator or torque convertor.

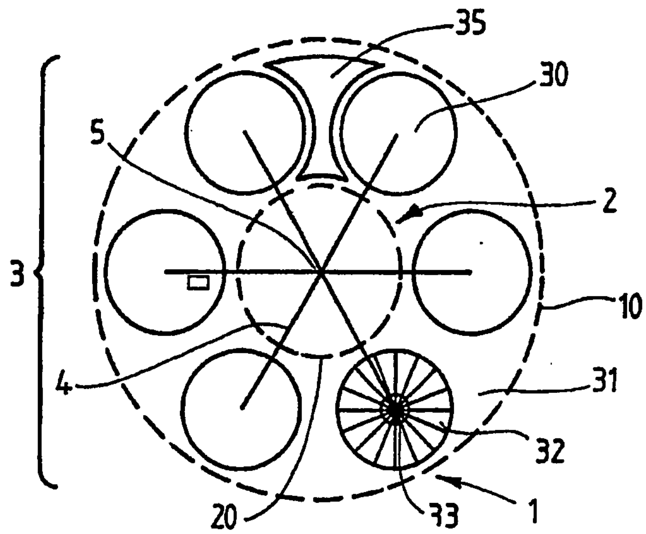

Fig. 1

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

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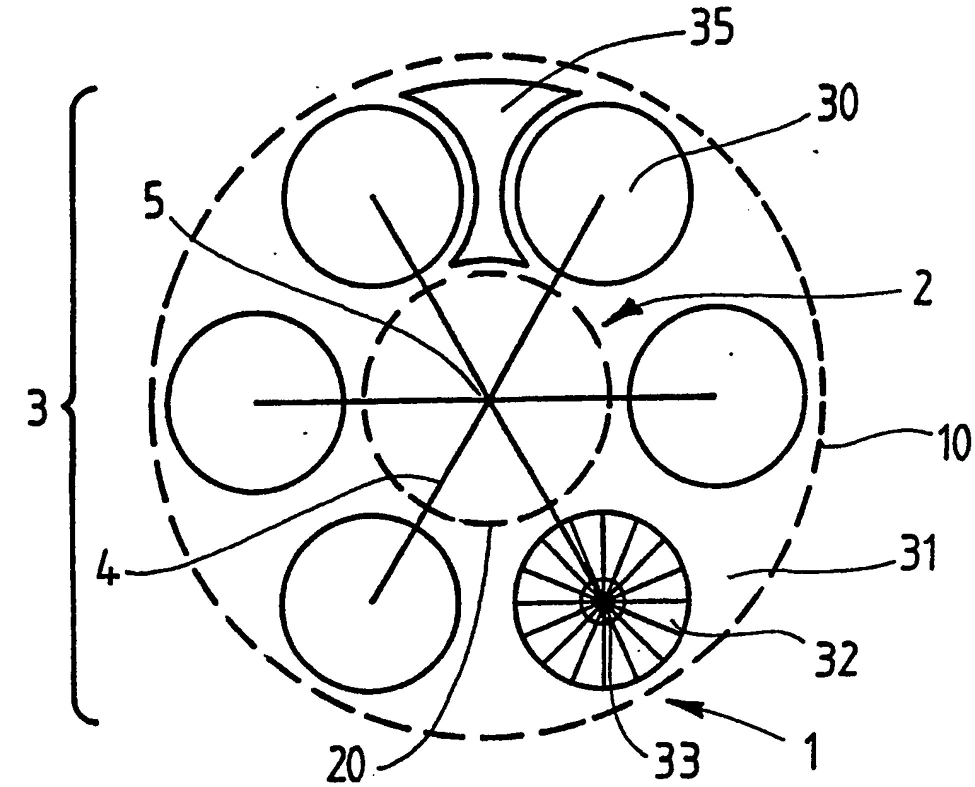

Fig. 1

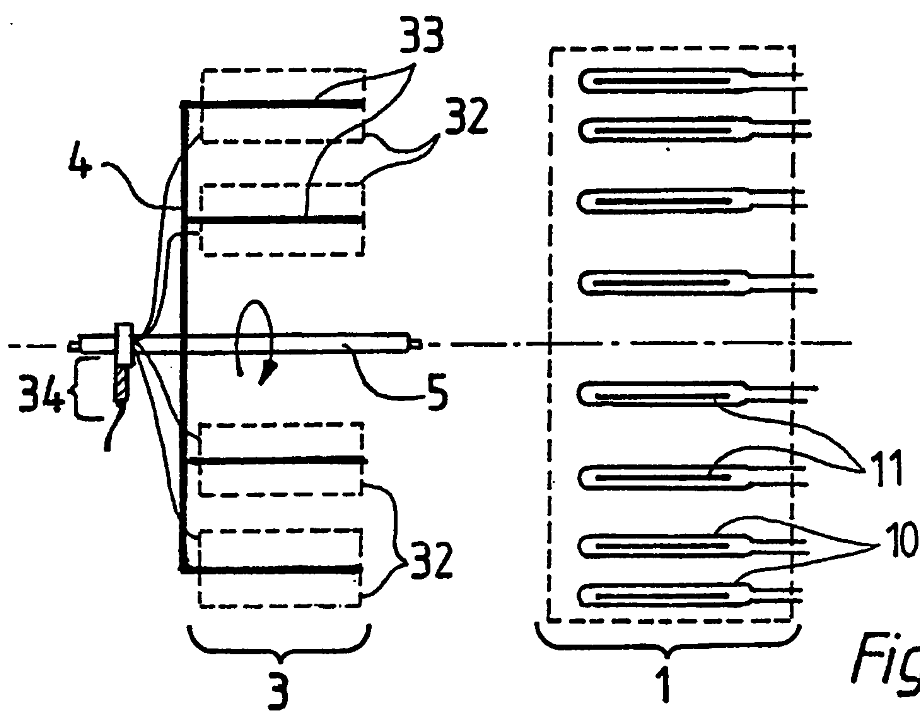

Fig. 2

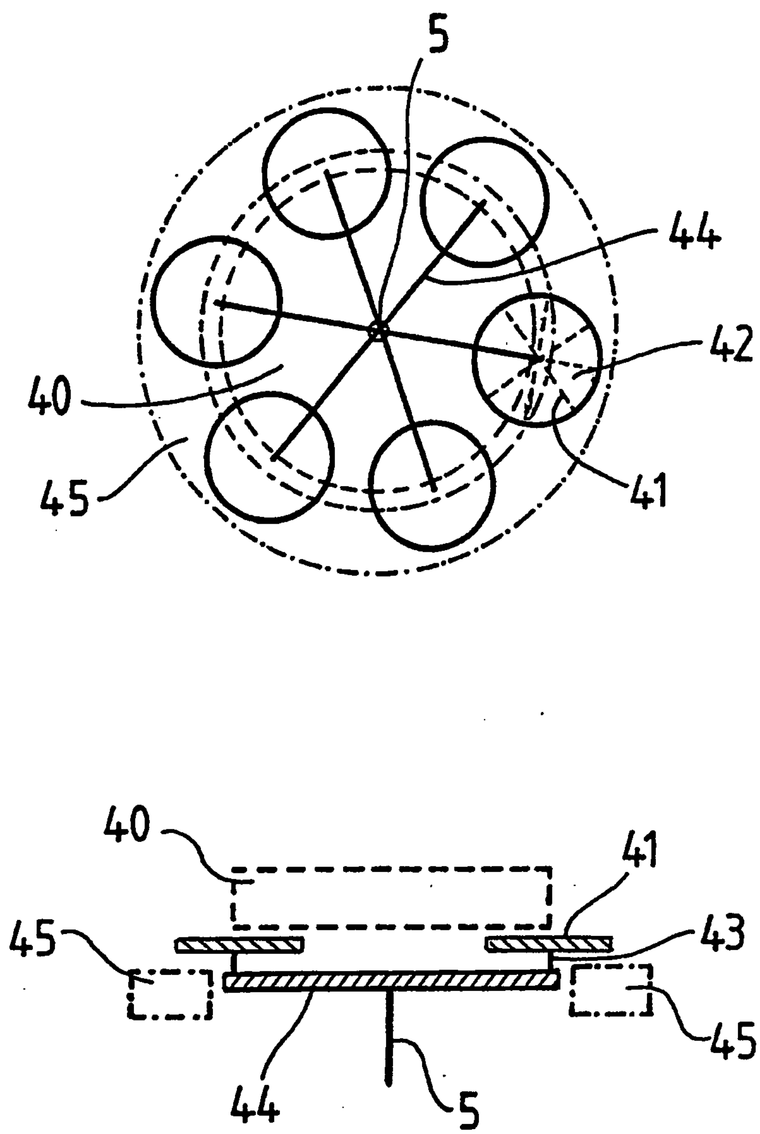

Fig. 3

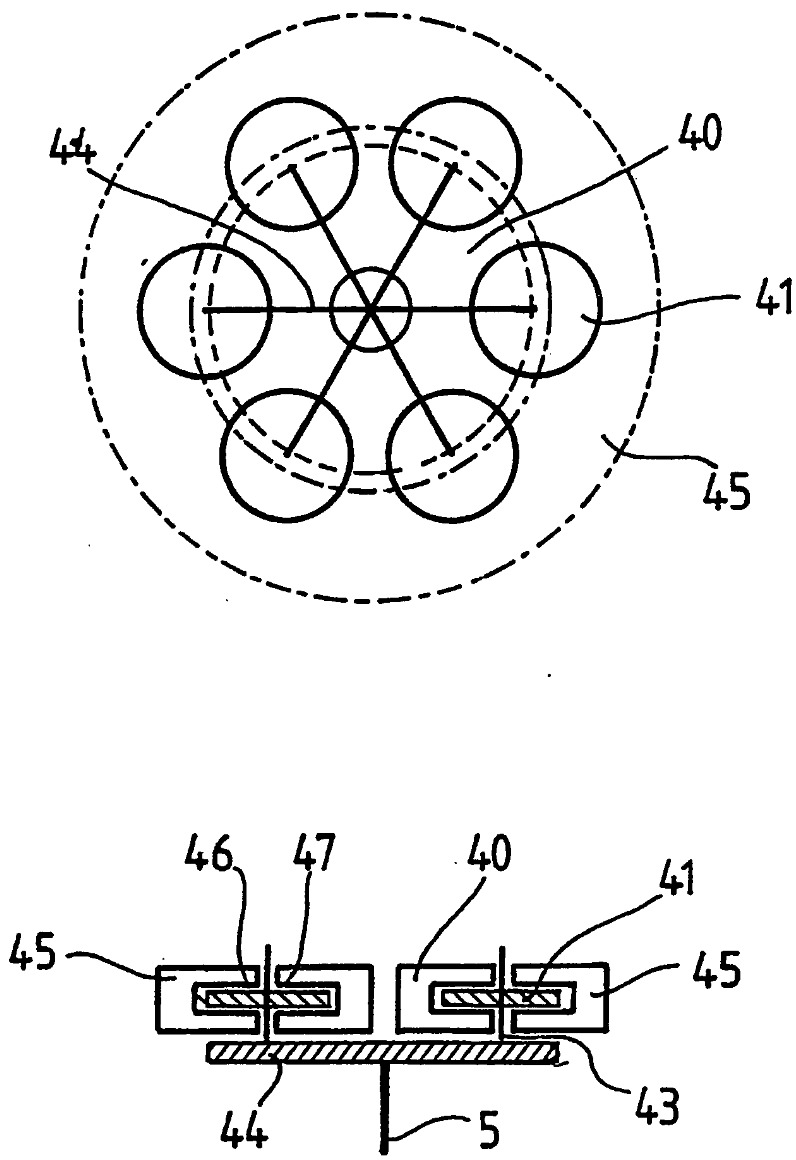

Fig. 4

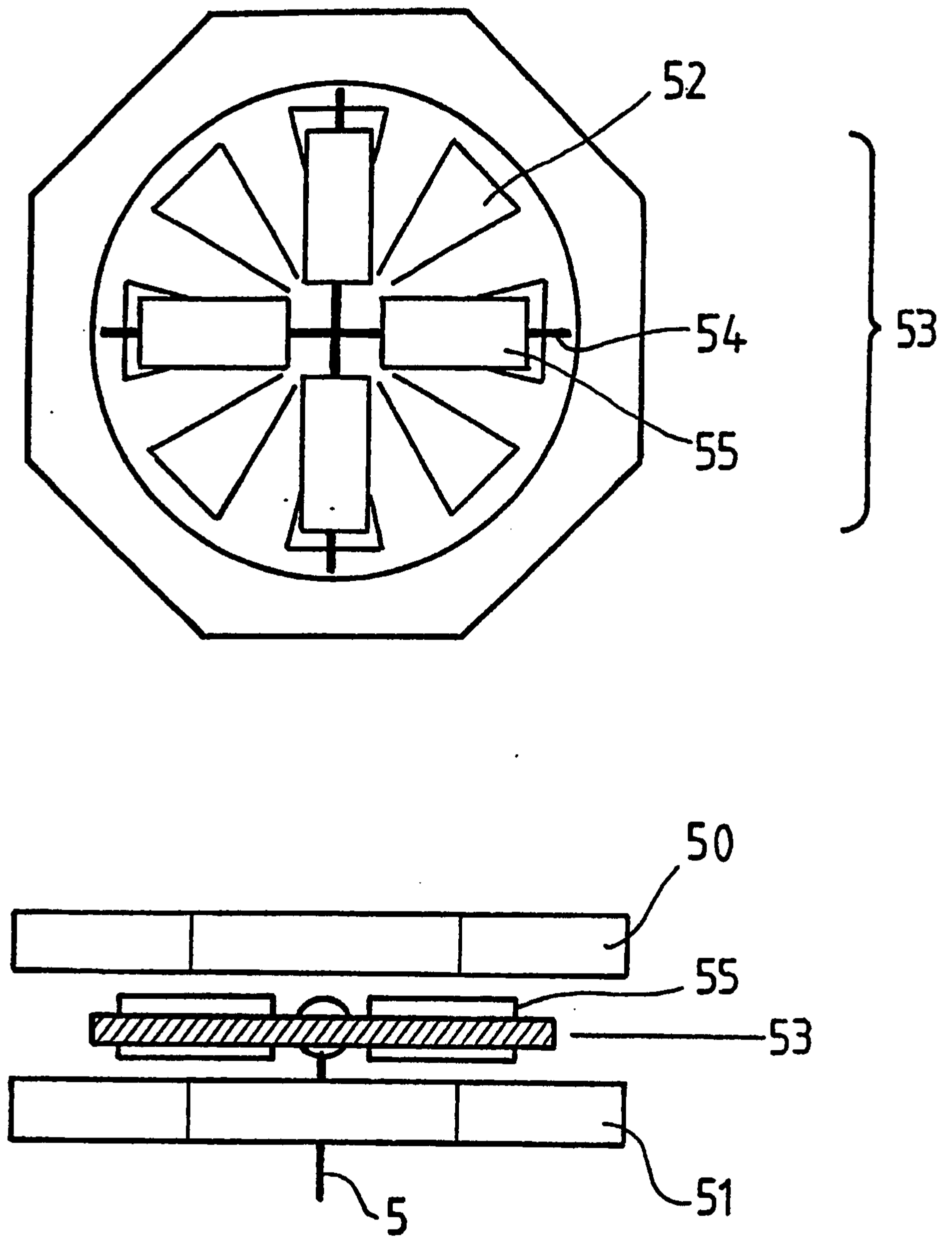

Fig. 5

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TITLE: ELECTRIC MOTOR

The present invention relates to an electric machine, notably one of an epicyclic construction, that can be used as a motor or generator.

BACKGROUND TO THE INVENTION:

Many types of electric motor or generator are known and used, for example induction, self-switching or asynchronous motors. Typically, these comprise a fixed outer stator, which is usually a series of coils to form an electromagnet, surrounding an inner rotating rotor to which current is often supplied by means of a commutator or slip ring device. Such forms of motor usually require some form of starter device in order to initiate rotation of the rotor and/or to avoid gross current overloading of the stator and/or rotor windings during start up. Furthermore, the motors often produce a torque which varies with the speed of rotation of the rotor and require an additional gearbox or other gearing mechanism so as to operate at their optimum torque output.

It has been proposed in US Patent No 4,649,307 that the motor should comprise an input drive shaft which drives an output shaft by means of a planetary type of coupling in which an intermediate rotatable member is magnetically coupled to the drive shaft so as to rotate the intermediate member; and the intermediate member is coupled to an outer ring member connected to the output drive. However, the coupling between the intermediate member and the output drive is by direct frictional engagement due to the radial outward movement of the intermediate member to engage an annular drive ring. Such a machine involves frictional slip between the drive components, which results in high wear between the drive components.

I have devised a novel form of machine which reduces many of these problems. For convenience, the invention will be described hereinafter in terms of the motor embodiment, although the principles underlying the invention may be applied to the design and construction of a generator or torque convertor.

SUMMARY OF THE INVENTION:

Accordingly, the present invention provides an electric machine, which comprises:

a. a first stator member and a second stator member substantially co-axial with but spaced from the first stator member to provide opposed generally parallel faces of said first and second stator members to either side of a space therebetween, said first and second stator members being adapted to co-operate magnetically with one another across said space either directly or via a rotor member;

b. an intermediate rotor member located in the space between the said opposed faces of the first and second stator members and substantially co-axial with said stator members and adapted to co-operate magnetically with at least one of said stator members; and

c. means for varying the magnetic field acting upon and/or being generated from one or more of the stator and/or rotor members:

and in that at least one of the stator and/or rotor members is adapted to rotate about its longitudinal axis without frictional or mechanical engagement between the rotor and either of the stator members;

and in that said stator members are each provided with one or more magnets, magnetisable members or conductors, which magnetics, magnetisable members or conductors are adapted to provide a magnetic field which acts upon an adjacent one or more of the rotor and/or stator members to provide a

magnetic coupling between said stator and said rotor member;
and in that said rotor member comprises a number of magnets, magnetisable members or conductors which magnets, magnetisable members or conductors are each rotatable about their own axis which is orientated generally parallel to said opposed faces of said stator members;
and in that at least one of the stator and/or rotor members is provided with means to provide a mechanical power output from or a mechanical power input to the machine.

Preferably, the machine of the invention is an electric motor, which comprises a first, preferably annular, stator member; a second stator member substantially co-axial with the first stator member, which is preferably annular and located within and having a substantially co-incident axis with the first stator member; an intermediate rotor member located in the space between the first and second stator members and substantially co-axial therewith; at least one of the stator and/or the rotor members being adapted to rotate about its longitudinal axis and at least one of the stator and/or rotor members being provided with one or more magnetic or magnetisable members, preferably a conductor adapted to carry an electric current and provided with means whereby an electric current can be passed through the said conductor so as to induce a magnetic field radiating therefrom, which magnetic or magnetisable member is adapted to provide a magnetic field which acts upon an adjacent one or more of the rotor and/or stator members so as to produce a torque thereon biassing the rotor and/or stator members to rotate relative to at least one of the other members; at least one of the rotor and/or stator members being provided with means, for example means for varying the frequency of the electric current passing therethrough, for varying the magnetic field radiating therefrom; one of the rotor and/or stator members by being mounted upon an axial shaft adapted

to be rotated about the longitudinal axis thereof by the rotatable member, so as to provide a mechanical power output from the motor.

The invention also provides a method for operating a motor of the invention, which method comprises causing the magnetic fields generated by at least the stator members to precess about the longitudinal axis of the rotor member, the frequency of precession of the field from the first stator being different from that of the second stator whereby the rotor member is caused to rotate.

The terms rotor and stator members are used herein for convenience to simplify identification of the members and to denote relative radial positions of the members, the rotor member being located intermediate the inner and outer stator members. The terms are not to be construed as denoting that a particular member is static or free to rotate. Thus, the outer stator member will usually, but not necessarily, be static so as to provide a fixed member against which the interaction of the magnetic forces between the inner and outer stator members and the intermediate rotor members can react. In some cases the intermediate rotor member can as a whole remain static, but its component members can be rotating so as to absorb the biassing torque of the magnetic fields acting upon the rotor member.

Preferably, the motor is configured as a radially symmetrical generally cylindrical construction, having an outer annular stator member surrounding an intermediate annular rotor member, with the second annular stator member mounted as a central member within the rotor member. It is also preferred that at least one of the stator members be fixed and that the rotor member be carried upon a spider or other assembly radiating from a central rotatable power

output shaft which is rotated as the rotor member rotates within the annular gap between the inner and outer stator members.

The rotor member comprises a series of axial or radial members, preferably in the form of axially or radially orientated magnetic or magnetisable members. These members are individually mounted upon their own shafts carried by the spider assembly so that each member can rotate about the longitudinal axis of its own shaft. Preferably, such a structure is made radially symmetrical about the longitudinal axis of the power output shaft.

The inter-action of the magnetic fields induced or emitted by the rotor and stator members causes the spider assembly and hence the power output shaft to rotate and the rotation of the members in the rotor member can be used to vary the speed of rotation of the power output shaft.

In a typical operation of the motor of the invention, the magnetic field from the first stator initially causes the members of the rotor member to rotate about their individual axes without rotation of the rotor member as a whole about its axis. The subsequent application of the magnetic field or field from the second and/or first stator member(s) opposes the rotation of the members in the rotor and thereby causes the rotor member as a whole to rotate. The speed of rotation of the rotor member is controlled by the relative frequency of precession of the magnetic fields emitted from the first and second stator members.

However, it is also within the scope of the present invention to form the motor as a pancake type of construction with the stator members in the form of parallel planar annular or disc-like members with one or more disc-like rotor members carried between them, the

stator and rotor members being mounted upon a substantially common axis.

In one form of such a pancake design, the rotor member preferably comprises a series of radial members each rotatable about its own radial shaft carried upon a central hub connected to the power output shaft. The stator members each comprise a disc or annular shaped member carrying radially disposed electromagnets, and are located parallel to the rotor, one above and one below the plane of the rotor member. Alternatively, the rotor member can comprise a number of transverse disc-like members each carried on an axial shaft which forms part of a spider assembly connected to an axial shaft. The stators are in the form of annular discs having their plane substantially parallel to the plane of the transverse members of the rotor member. One stator member is located to one side of the rotor and is dimensioned so that it acts upon the radially outward portion of the rotatable members, the other stator is located to the other side of the rotor member and is dimensioned so that it acts upon the radially inward portions. In this design, the rotatable member are caused to rotate about their axes by one stator member and the other stator member opposes that rotation so as to cause the rotor member as a whole to rotate.

For convenience, the invention will be described hereinafter in terms of a series of concentric generally cylindrical rotor and stator members and in terms of a motor where the mechanical power take off shaft is driven by a spider assembly carrying the intermediate rotor member. However, it is also within the scope of the present invention for the mechanical power take off to be direct from one or more of the stator members or through a planetary or other ring gear carried by a stator member which is caused to rotate through the interaction of

magnetic field forces generated by the other stator and the intermediate rotor members.

The motor of the invention can be constructed and operated as an induction motor with the stator members formed as a series of axially aligned electromagnetic coils which are provided with suitable connection to a current source. Alternating current is supplied, or with suitable switching mechanisms a direct current is applied, to the stator, whereby the magnetic field induced in the coils of the stator member is caused to precess circumferentially. The rotor member is formed from a suitable permanent magnet or from a magnetisable material, for example as a series of axial bars carried by the spider assembly.

The inner stator member is preferably of a construction similar to that of the outer stator member, but need not have the same number of axially orientated coils, nor need these be radially in register with the coils in the outer stator member.

The rotor member is caused to be rotated by the action of the magnetic field generated by the stator members upon it. The inner stator member provides a second magnetic field which can oppose or supplement that from the outer stator member so as to provide a measure of regulation of the torque acting on the spider assembly and hence the speed and power of the output shaft.

As indicated above, the rotor member comprises a series of axially orientated conductors which are each mounted upon an axially orientated shaft rotatably mounted upon the spider member. The magnetic field from the outer stator causes the axial members to rotate about their longitudinal axes, without causing the spider assembly to rotate. As current is applied to the inner stator, the frequency of

this current relative to that in the outer stator is altered so as to oppose the rotation of the axial members and thus cause the spider assembly to rotate about its longitudinal axis and thus rotate the power output shaft. By varying the frequency, amplitude and relative phasing of the currents applied to the inner and outer stators, for example by applying an AC current to the outer stator and a DC current to the inner stator, the power output and the speed of the output shaft can be varied without the need for complex gearing mechanisms.

The mechanism for varying the current applied to the two stator electromagnetic assemblies can be of conventional form and operation.

In a particularly preferred embodiment of the invention, electrical current is applied through a suitable slip ring or commutator assembly to the axial conductors of the rotor member so that they also generate a magnetic field. This can interact with an electromagnetic field from permanent or electromagnetic coils or the like in the inner and outer stator members. It is particularly preferred that such an electromagnetic rotor member be used in conjunction with stators which have electromagnets as described above to provide interacting magnetic fields from all three members. The generation of effectively three independently controlled magnetic fields enables the operator to have a wide range of control over the power output of the motor and the speed and direction of rotation of the power output shaft by varying the amplitude, frequency and phase of the voltages applied to the various electromagnetic coils present in the stator and rotor members.

DESCRIPTION OF THE DRAWINGS:

To assist understanding of the motor of the invention,

various forms thereof will now be described with reference to the accompanying drawings in which Figure 1 is a diagrammatic transverse cross-section through the motor; Figure 2 is a diagrammatic axial cross-section through one form of the rotor and outer stator of the motor shown in Figure 1, with the stator off set to the right to display the rotor within it; and Figures 3 to 5 are diagrammatic plan views and axial cross-sections through three different pancake forms of the motor of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

The motor comprises an annular outer stator member 1, encompassing an inner annular stator 2 and an intermediate annular rotor member 3 carried upon radial arms 4 from a central rotatable power output shaft 5 forming the spider assembly.

With the form of motor shown in Figure 1, the outer stator 1 is preferably formed from a series of axially orientated electromagnetic coils 10 fed with electrical current through a suitable switching mechanism (not shown) or a single or multi-phase alternating current, so that opposed coils in the stator are energised in sequence to form a magnetic field which precesses circumferentially around the stator members. The coils, their construction, orientation and circumferential spacing and coupling can be similar to those used in the design and manufacture of the field windings for a conventional electric motor, for example axially orientated coils 10 can be wound upon iron or other magnetisable cores 11. The frequency and amplitude of the currents fed to each stator are individually selectable or controllable using known techniques so that the magnetic fields from the inner and outer stators can precess at different rates.

Alternatively, the stator 1 can consist of a series of axially orientated permanent magnets in place of the coils 10. However, this reduces the flexibility of operation of the motor, since it is not possible to vary the size and phase of the magnet field as the rotor member 3 rotates within the stator 1, as when electromagnetic coils or field windings are used.

The inner stator member 2 is conveniently of the same general design and construction as the outer stator 1, except that the inner stator 2 will usually be supplied with electrical power at a different frequency to that applied to the outer stator and the coils or field windings 20 of the inner stator 2 need not be radially in register with those of the outer stator 1.

As indicated above, it is preferred that the outer stator 1 be fixed, for example by being secured to the housing of the motor, as with the field windings of a conventional motor. It is also preferred that the inner stator 2 be fixed, for example by also being secured to the housing of the motor. However, the inner stator can be mounted so that it is carried upon the central power output shaft 5 or so that it is free to rotate about that shaft. For convenience, the invention will be described in terms of a motor having both the inner and outer stator members fixed to the housing of the motor with the intermediate rotor member 3 rotatable within the annular gap between the inner and outer stator members 1 and 2.

The rotor member 3 can merely be a series of longitudinal permanent magnets or magnetisable members 30, for example mild steel rods or bars, lying axially within the gap 31 between the inner and outer stator members and having their ends supported by radial arms 4 extending symmetrically from the power output shaft 5 to form a cage assembly.

As stated above, the different frequencies of the currents applied to the inner and outer stators cause the magnetic fields induced in the windings 10 and 20 of the stator members 1 and 2 to precess at different rates and thus apply a torque to the rotor assembly to cause the cage assembly to rotate about the longitudinal axis of shaft 5. The speed of rotation is controlled by the rate of precession of the induced magnetic fields. The amplitude and relative frequency of the currents applied to the stator members alter the speed of rotation and the power output from shaft 5.

However, it is preferred that the axial members 30 of the cage assembly be formed as electrical conductors, for example as axially orientated wires or the like, so that a variable radial magnetic field can be generated from those conductors to interact with the magnetic fields from the inner and outer stator members. The conductors can also be formed as electromagnetic coils or windings, similar to those in the inner and outer stator members, so that axial magnetic fields are generated. For convenience, the invention will be described in terms of the generation of radial magnetic fields around axially orientated conductors 30 carried by the rotor member 3.

As stated above, the axial conductors 30 of the rotor member can be fixed. However, it is preferred that they are mounted so that they can rotate about their longitudinal axes in the manner of the rotors of a conventional motor. Thus, the rotor assembly 3 can comprise a series of axially orientated rotor windings 32 upon an axial bobbin carried on an axial shaft 33, shown diagrammatically as the single axial line 32/33 in Figure 2. Current is fed to the windings 32 by suitable brush/commutators or slip ring connections 34.

Where the rotor 3 comprises axial conductors 30 or rotors, it may be desired to provide axial ferromagnetic shaping elements 35 between the conductors so as to shape the magnetic field. Such shaping members can be of conventional form and construction and need not be of the shape shown in Figure 1.

The current fed to the various components of the motor can be regulated by any suitable control circuit as used in the art. For example, where an alternating current is applied to both the inner and outer stator members, it may be necessary to shift the phase of the supply to one stator relative to the other to initiate rotation of the rotor member or to provide a secondary starting phase for either of the stators.

As indicated above, where the axial conductors or magnets 30 of the rotor member 3 are fixed, the speed and direction of rotation of the rotor member is governed by the relative frequency and amplitude of the currents applied to the inner and outer stator members, as well as the relative size and location of the coils in each stator. However, where the rotor comprises rotatable axial magnets or conductors, this rotation can be used to provide an idling mode for the motor where the axial magnets or conductors rotate to absorb the torque generated by the magnetic field from the outer stator member. Application of current to the inner stator and/or to the rotor conductors acts to restrict the free rotation of the axial members of the rotor member and causes the rotor member as a whole to rotate about its longitudinal axis. This thus provides a means for reducing the electrical load on the windings of the rotor and stator members during initial start up and a simple means for varying the speed of rotation of the power output shaft 5 without the need for a gearing mechanism.

Figures 3, 4 and 5 show alternative designs to the motor of Figure 1 where the stators and rotors are orientated transversely to one another rather than axially.

In the form of motor shown in Figure 3, one stator 40 is formed as a disc having a number of radially orientated electromagnets therein (not shown). A series of disc-like rotors 41, preferably each having a series of radial electromagnets 42 (shown dotted), are mounted with their planes parallel to that of stator 40 upon axial shafts 43 carried by radial arms 44 from power output shaft 5. The second stator 45 is located below the plane of the rotors 41 and is in the form of an annular ring of electromagnets. The upper stator 40 acts upon the radially inward portion of the rotors 41 to cause them to rotate in one direction. The lower stator 45 acts on the radially outward portion of the rotors 41 and can be operated so as to oppose the rotation inducted by stator 40. Initially, when current is fed to stator 40, the rotors 41 rotate about their individual axes 43. When current is applied, preferably at a different frequency, to stator 45, this opposes the rotation of the rotors 41 about their axes and causes the whole rotor assembly to rotate about the axis of shaft 5.

In the form of motor shown in Figure 4, the stators 41 and 45 are each formed as an annulus with a C cross-section to provide a pole gap 46, 47 between the free ends of the C. The two stators are substantially coplanar with the rotors 41 located in the pole gaps 46, 47.

In the form of motor shown in Figure 5, the upper and lower stators 50 and 51 are substantially similar annular rings of radially orientated electromagnets 52 positioned parallel to each other above and below the plane of the rotor assembly 53. The rotor comprises the power output

shaft 5 carrying radial shafts 54 upon which are rotatably journalled rotor units 55, which are preferably similar to the rotor units of a conventional electric motor and are fed with electric current through a slip ring or commutator assembly, not shown.

The invention has been described above in terms of a motor. However, it will be appreciated that the design can be applied to a generator and that such a generator falls within the scope of the present invention.

CLAIMS:

1. An electric machine, which comprises a first stator member; a second stator member substantially co-axial with but spaced from the first stator member, said first and second stator members being adapted magnetically to co-operate with one another either directly or via a rotor member; an intermediate rotor member located in the space between the first and second stator members and substantially co-axial therewith; at least one of the stator and/or the rotor members being adapted to rotate about its longitudinal axis; said stator and rotor members each being provided with one or more magnetic or magnetisable members, which magnetic or magnetisable member is adapted to provide a magnetic field which acts upon an adjacent one or more of the rotor and/or stator members to provide solely a magnetic coupling between said stator and said rotor member; said rotor member comprising a number of magnets, magnetisable members or conductors carried by a spider assembly, which magnets, magnetisable members or conductors are each rotatable about their own axis upon a shaft carried by the spider assembly; means for varying the magnetic field acting upon one or more of the stator and/or rotor members; at least one of the stator and/or rotor members being provided with means to provide a mechanical power output from or a mechanical power input to the machine.

1. An electric machine, which comprises a first stator member; a second stator member substantially co-axial with but spaced from the first stator member and adapted to co-operate therewith; an intermediate rotor member located in the space between the first and second stator members and substantially co-axial therewith; at least one of the stator and/or the rotor members being adapted to rotate about its longitudinal axis and at least one of the stator

and/or rotor members being provided with one or more magnetic or magnetisable members, which magnetic or magnetisable member is adapted to provide a magnetic field which acts upon an adjacent one or more of the rotor and/or stator members; means for varying the magnetic field from one or more of the stator and/or rotor members; at least one of the stator and/or rotor members being provided with means to provide a mechanical power output from or a power input to the machine.

2. An electric machine as claimed in claim 1 in the form of an electric motor, which comprises a first stator member; a second stator member substantially co-axial with the first stator member and spaced therefrom; an intermediate rotor member located in the space between the first and second stator members and substantially co-axial therewith: at least one of the stator and/or the rotor members being adapted to rotate about its longitudinal axis and at least one of the stator and/or rotor members being provided with one or more magnetic or magnetisable members which are adapted to provide a magnetic field which acts upon an adjacent one or more of the rotor and/or stator members so as to produce a torque thereon biassing the rotor and/or stator members to rotate relative to at least one of the other members: at least one of the rotor and/or stator members being provided with means for varying the magnetic field radiating therefrom; one of the rotor and/or stator members by being mounted upon an axial shaft adapted to be rotated about the longitudinal axis thereof by the rotatable member, so as to provide a power output from the motor.

3. A machine as claimed in either of claims 1 or 2, wherein the first stator is of annular configuration, the second stator is of annular configuration and located within and having a longitudinal axis which is

substantially co-incident with that of the first stator; the rotor is located within the annular space between the stators.

4. A machine as claimed in any one of the preceding claims, wherein the magnetisable members are conductors through which an electric current is to be passed and variation of the magnetic field from those members is achieved by varying the frequency of the current in the conductors.

5. A machine as claimed in any one of the preceding claims, wherein the rotor member comprises a number of magnetisable members or conductors carried by a spider assembly upon a rotatable shaft which provides the mechanical power input or output means.

6. A machine as claimed in claim 5, wherein the magnetisable members or conductors are each rotatable about their own axis upon a shaft carried by the spider assembly, whereby rotation of the magnetisable members or conductors can absorb at least part of the torque biassing the rotor member to rotate.

7. A machine as claimed in any one of the preceding claims, substantially as hereinbefore described with respect to and as shown in any one of the accompanying drawings.

8. A method for operating a motor as claimed in any one of the preceding claims, which method comprises causing the magnetic fields generated by at least the stator members to precess about the longitudinal axis of the rotor member, the frequency of precession of the field from the first stator being different from that of the second stator whereby the rotor member is caused to rotate.

9. A method as claimed in claim 8, wherein the motor is a motor as claimed in claim 6 and initially the field from the first stator causes the magnetisable members or conductors of the rotor member to rotate about their individual axes without rotation of the rotor member as a whole about its axis; and the subsequent application of the magnetic field from the second stator member opposes the rotation of the magnetisable members or conductors and thereby causes the rotor member as a whole to rotate; and the speed of rotation of the rotor member is controlled by the relative frequency of precession of the magnetic fields emitted from the first and second stator members.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9220384.3

I ;vant Technical Fields

(i) UK Cl (Ed.L) H2A (AKQ1, AKQQ, AKS7, AKR7, AKR8, AKR9)

(ii) Int Cl (Ed.5) H02K

Search Examiner
D J HARRIS

Date of completion of Search
25 NOVEMBER 1993

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ON-LINE DATABASE: WPI

Documents considered relevant following a search in respect of Claims :-
1-9

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2139821 A	(CATERPILLAR) see Figure 1	1(b)
X	GB 1489055 A	(DUPONT) see Figure 1A	1(b) and 2, 3
X	EP 0071387 A2	(GENERAL SIGNAL) see Figure 4 page 8 lines 6-16	1(b) and 2, 3
X	US 4532447 A	(CIBIE) see Figure 6 and abstract	1(b) and 2, 3

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).